PaperID **AU168**

Author **JAI PRAKASH SRIVASTAVA , OIL AND NATURAL GAS CORPORATION LIMITED , India**

Co-Authors **S.Kamble, M.B. Bhalerao**

Real time reservoir data monitoring & interpretation improves operational efficiency & better reservoir characterization: A case study of Western offshore basin

Abstract

Well testing generates essential reservoir data necessary for reservoir characterization and establish well deliverability. Many a times it has been observed that an operationally successful well test turns out to be a practical failure, simply because the study was terminated prematurely or prolonged unnecessarily. To overcome this problem, surface read-out (SRO) systems can be used with DST for retrieving downhole memory gauge data in real time; thus, the pressure response can be monitored directly, and the operational changes can be made immediately, based on actual reservoir conditions.

An acoustic SRO system with TCP- DST string was deployed in Western offshore basin for exploratory well testing of well W-3. By availability of real time data, the shallower interval was evaluated first and deeper interval was added by cross firing producing commingle later. It was observed that permeability of the shallower tested interval was good. Pressure transient analysis from real time SRO data indicated that the well is having composite behaviour (deterioration of facies away from wellbore). The combine testing of intervals reveal that prolonging testing time would not be reasonable when reviewing operational and economic considerations. The prompt data delivery facilitated reservoir engineers at base providing flexibility to optimise well test program from planned 216 hrs to 98 hrs, resulted in saving of 118 hours of rig time equivalent to USD$322,385.

Introduction

W-3 is an exploratory well situated to the south of Mumbai High field in Western offshore basin (Figure-1).The purpose of the testing was to identify reserves to justify further delineation of the field.

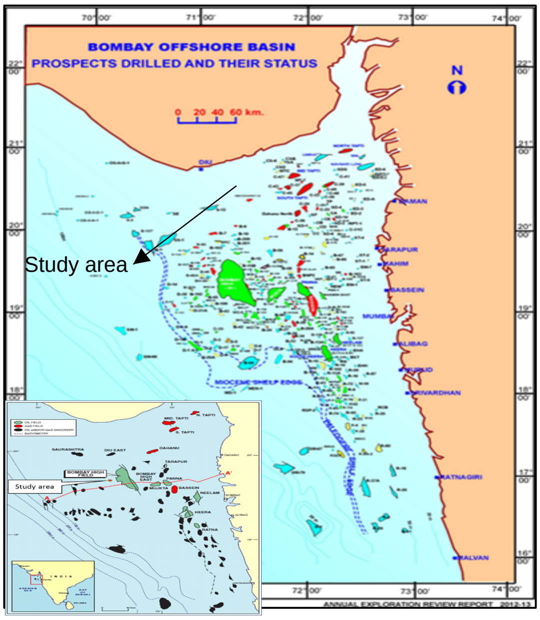

Figure 1: Field location in Western offshore basin of Mumbai offshore block

For effective pressure transient analysis, Real time Surface read out (SRO) system using acoustic mode was used keeping following advantages in mind:

- *Flexibility*: By allowing immediate and better decision making with rapid data interpretation and remote expert support.
- *Quality*: By ensuring downhole real time DST data obtained is attaining the necessary testing objectives.
- *Cost*: Reducing testing time through optimized clean-ups and shorter well test duration.
- *Safety*: By eliminating wireline intervention hence reducing health and safety hazards of personnel exposure to H2S and other toxic fluids.

Well W-3 was very important for field development as this was a new area and proper reservoir testing will aid in better estimation of reserves and help in further project development.

In well W-3, SRO was used in combination with tubing conveyed perforation (TCP) and DST assembly which was provided by M/S EXPRO. DST assembly involves equipment for temporary completion of well. The DST tools enables shutting in of well near the sand face, thus minimizing the wellbore storage effects.

The SRO system is an acoustic telemetry system that uses acoustic vibrations in the tubing string to transmit information. Repeater stations are installed along the length of tubing string to overcome the acoustic signal attenuation and distortion.

The results showed that the implementation of SRO system could aid in saving valuable time and money by providing real time pressure and temperature measurement and prompt decision making.

Case Study

After completion of drilling of well W-3 based on logs recorded, one object (siltstone) with two intervals of 2.5m KBTVD separation between them were identified for testing. The well test study was planned with DST gauge so as to include sufficient time for well clean-up, sufficient flow periods and large enough build up to record any reservoir boundary.

The planned sequence of operations involved were as depicted in schematic diagram. (Figure-2)

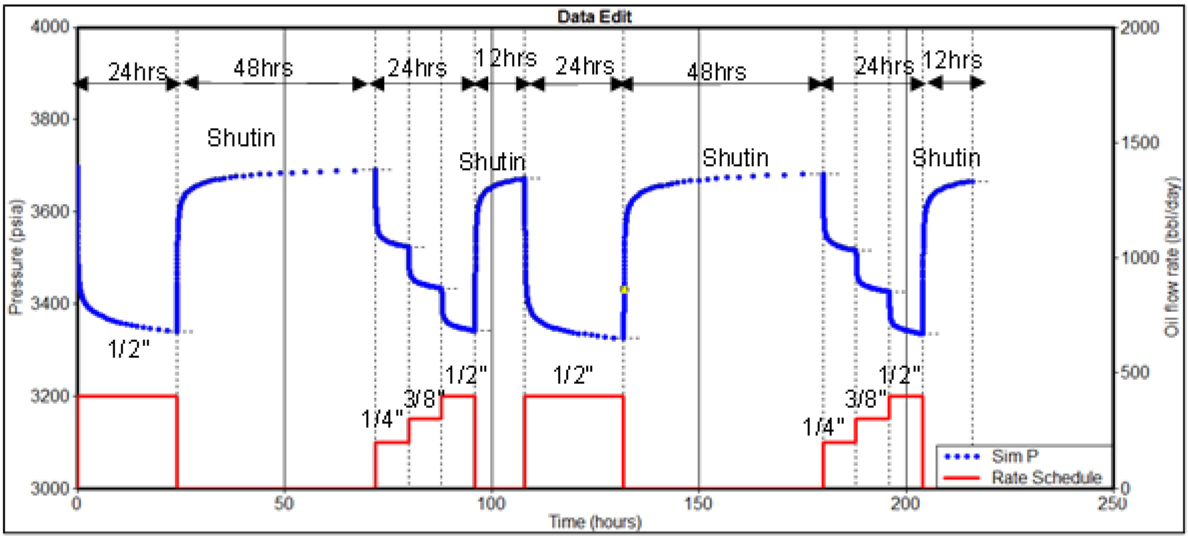

Figure-2: Schematic showing planned well testing operation sequence

During MDT the shallower interval indicated oil (formation Pressure 3972.5psia at 2575m KBTVD) and deeper interval indicated oil and water (formation Pressure 3971.4psia at 2571.62m KBTVD). It was decided to test shallower interval first and evaluate, considering presence of water in deeper interval.

After perforation of shallower interval, the well was opened and kept under observation. Real-time bottom-hole pressure and temperature data was acquired and delivered by SRO acoustic tool. (Figure-3).

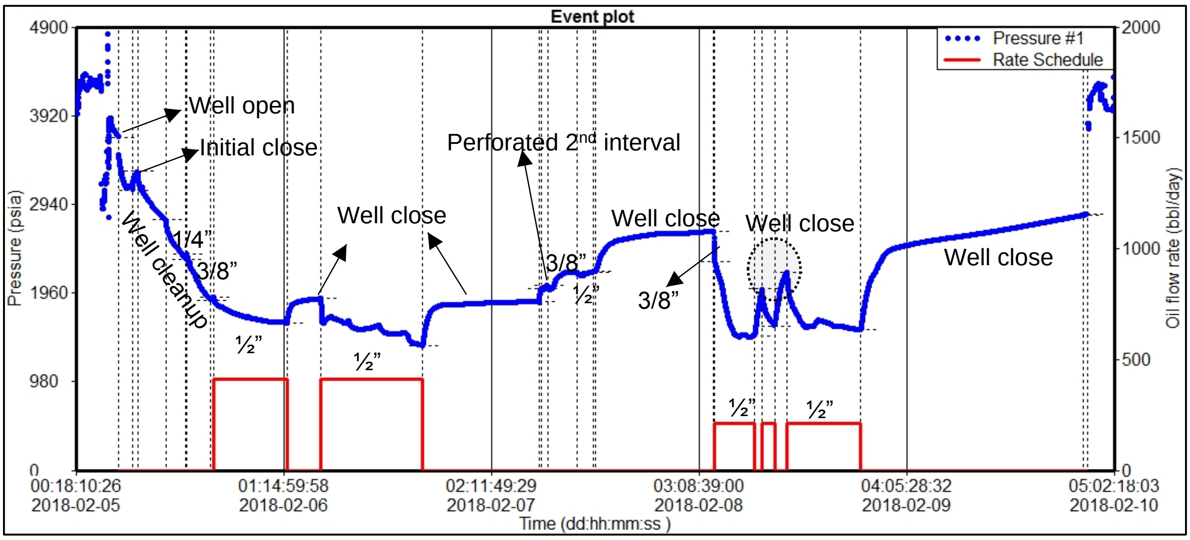

Figure-3: Event plot of Object - I

After clean-up, well was closed for initial build-up (recorded shut-in pressure as 3308.207 psia at 2523.22 m KBTVD gauge depth), again well was open, flow rate was measured (oil rate of 409 bpd thru ½” choke and flowing pressure of 1378.88 psia at 2523.22 m KBTVD gauge depth) and well was shut-in at surface for build-up (recorded shut-in pressure as 1867.071 psia at 2523.22 m KBTVD gauge depth). It was observed that there is decrease in shut-in pressure during subsequent build-up’s indicating either the reservoir is closed or decrease in flow capacity away from wellbore. Pressure build-up study was carried out considering oil as single phase fluid. PVT parameters were generated by considering standing correlation available in Pansystem software

The pressure derivative on log log plot given in fig.4 was used to identify the flow regime and it is observed that after well bore storage an indication of phase segregation is observed after which the IARF is seen indicating a good permeability 83md with no well bore damage of skin (-ve) 0.8. After IARF the derivative shows a steep rising trend indicating multiple boundaries/composite behaviour. The structure contour map was look into to corroborate the presence of boundary but no boundary is present in vicinity with respect to the radius of investigation of less than 500 feet, hence this increase in derivative might be due to composite behaviour of the reservoir. The last end points of pressure build-up were extrapolated to estimate the current reservoir pressure on radial flow plot which gives value of 1927.27 psia at 2523.22 m KBTVD gauge depth.

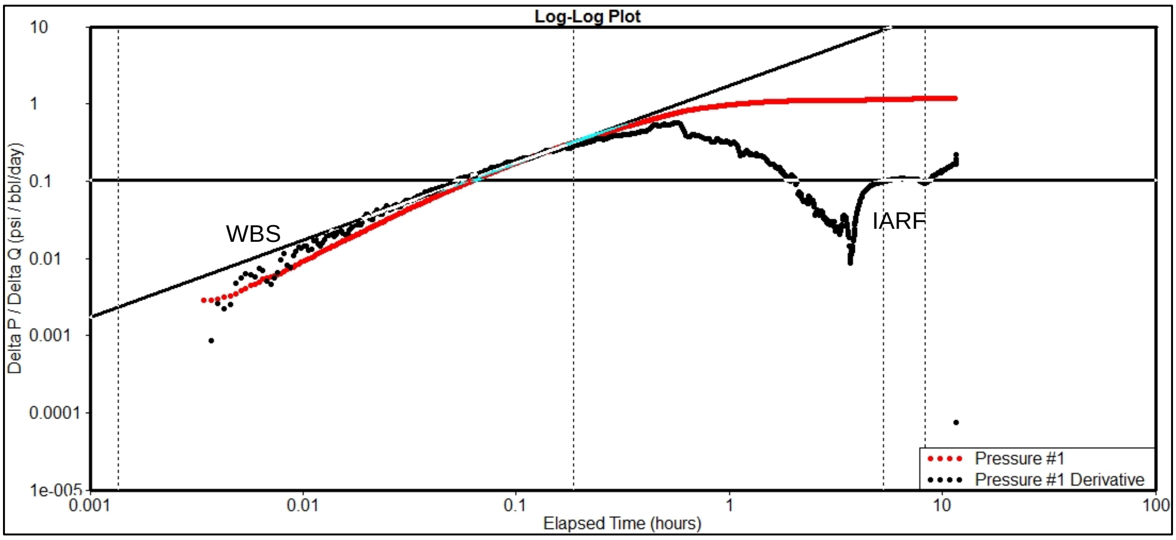

Figure -4: Log-Log plot of Pressure Build-up of Object-I (Shallower Interval)

The study was terminated at this point and it was decided to perforate the deeper layer without pulling out the DST string. Later the well was cleaned up; the rate was measured thru ½" choke with oil rate of 212 bpd and flowing pressure of 1555.647 psia at 2523.22 m KBTVD gauge depth. Further well was closed for BUP study (recorded shut-in pressure as 2818.708 psia at 2523.22 m KBTVD gauge depth). The pressure derivative plot (fig.5) shows the initial radial at 7.7 hrs of BUP after which the derivative shows a steep increase in derivative and it continues till the end of BUP at 22.2 hrs. This increase in pressure derivative of BUP indicates decrease in kh(flow capacity).

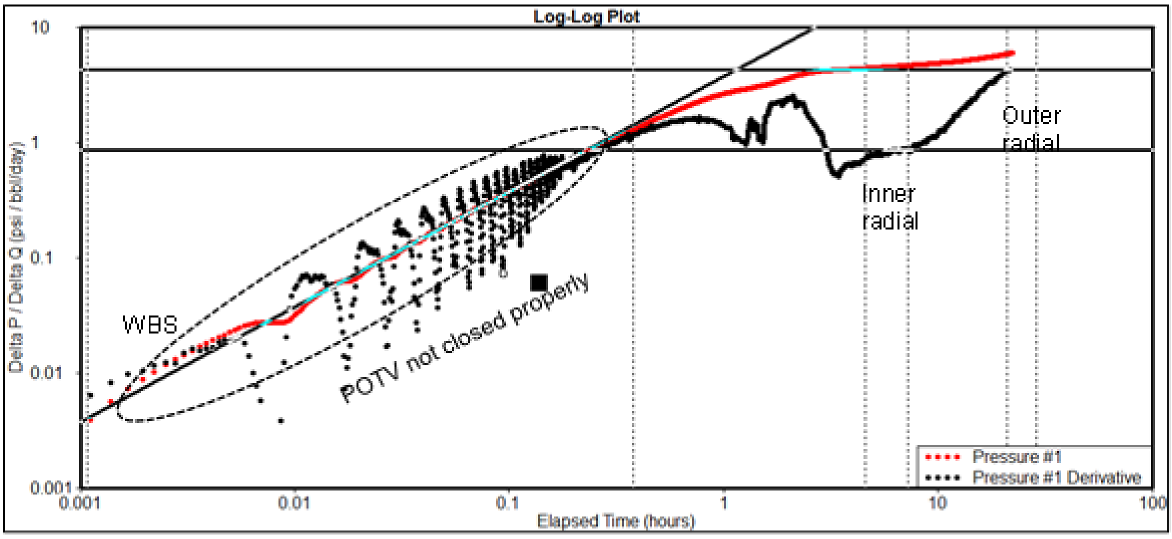

Figure -5: Log-Log plot of Pressure Build-up of Object-I (Shallower & deeper Interval)

To estimate the reservoir parameter, radial composite model was selected and the end of the derivative was taken as outer radial. The inner radial represents permeability of both the layers of 5.49 md which indicates tightness of one layer but as shallower layer is permeable so it deduces that deeper layer is tight. Middle region of pressure derivative plot after radial flow show chances of cross flow though wellbore between layers due to pressure difference. First build-up of reservoir shows Pressure of 1927.9 psia and combined build up shows 3613.02 psia at 2523.22 m KBTVD gauge depth which is near about MDT pressure. The derived effective permeability of combined layer is very much lower than the effective permeability derived for the single layer. This might be due to the low permeability of the deeper interval as compared to the shallow interval which was perforated.

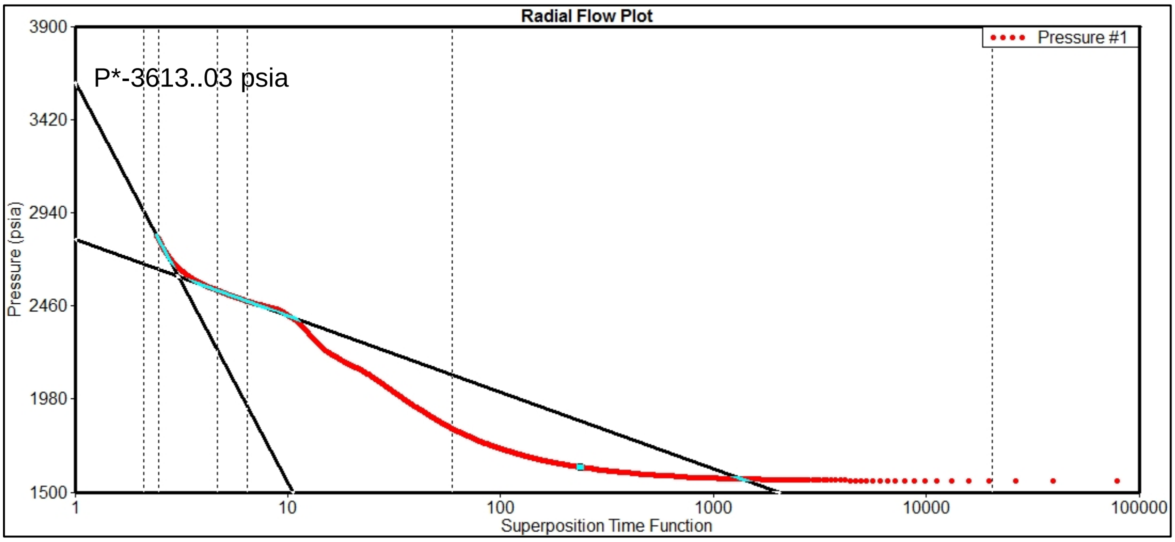

Figure -6: Semi-log plot of Pressure Build-up of Object-I (Shallower & deeper Interval)

It was decided to terminate the testing, since both the intervals were evaluated with the estimation of reservoir parameters without pulling out of DST string which resulted in the significant saving of around 118 hrs of well testing rig time against the planned reservoir study time of 216 hrs.

Conclusions

Online interpretation reveals that after addition of deeper interval, the system permeability of deeper interval is very poor (due to facies variation away from wellbore) resulting in longer stabilisation time for reservoir pressure.

The use of SRO in W-3 proved to be very helpful in justifying operational flexibility and successful decision making. More than 118 hrs. of rig time was saved which mounted to USD$322,385 in costs for exploratory well testing.

The prompt data delivery facilitated subject matter experts at base, flexibility to optimise the testing program to 98 hrs against the planned 216 hrs of well test program.

Acknowledgement

The authors sincerely acknowledge the ONGC authority for permitting to publish the data and the findings of the study. Authors wish to express gratitude to M. Ayyadurai, ED-Basin Manager for his guidance during testing of exploratory well. The authors are thankful to Shri P.K. Dileep, ED Asset Manager of MH Asset for providing an opportunity, encouragement, infrastructure and technical support. Thanks are due to Shri D. K. Nautiyal, SSM, MH Asset for their keen interest and valuable guidance.

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